was seemingly due to the magnetic poles diversely influencing the action of the solution on the metal; and in the case of the copper salts, the ratio of the electro-deposition of the copper was apparently affected by these magnetic influences. It may be remarked that this research has been replete with difficulties of various kinds, and about 386 magnets have been experimented upon in Part III with the various solutions to endeavour to ensure accuracy in the observations recorded.

II. "Report on the Effects of Contact Metamorphism exhibited by the Silurian Rocks near the Town of New Galloway, in the Southern Uplands of Scotland." By S. ALLPORT, F.G.S., and T. G. BONNEY, D.Sc., F.R.S.* Received May 7, 1889.

In the 'Transactions of the Royal Society of Edinburgh' (vol. 7, p. 79) is a paper by Sir John Hall, in which he says that he read to that Society, in the year 1790, an account of his observations on the granitic mass of Loch Ken.. In this he stated that in all the "extent where the junction of the granite with the schistus was visible, veins of the former, from 50 yards to the tenth of an inch in width, were to be seen running into the latter in all directions, so as to put it beyond all doubt that the granite of those veins, and consequently of the great body itself, which I observed forming with the veins one continuous and uninterrupted mass, must have flowed in a liquid state into its present position."

Of the accuracy of these observations no competent observer can entertain a doubt, and microscopic examination of the rocks invaded reveals the great structural and mineralogical changes which have been produced by the intrusive granite. The portion of the altered Silurian strata examined by Mr. Allport forms a narrow band between the margin of Loch Ken and the granite *massif* of Cairn Muir and Cairn Fleet on the other. Starting from Lochside Point (about 2 miles south of New Galloway), and following a line drawn along the west side of the loch in a northerly direction, the altered

* The origin and authorship of this communication should perhaps be explained. In 1880 a grant was made by the Royal Society to Mr. S. Allport to enable him to study the phenomena of contact metamorphism in southern Scotland. Shortly before going there, he received an appointment at Mason's College, Birmingham, which for a while took up his whole time; and then a severe illness obliged him to lay aside for many months all scientific work. Last autumn, being still far from strong, he consulted me as to the best way of indicating that the above-named grant had not been without fruit, and, after some consideration, it was arranged that I should work over his specimens, and embody his notes with my own impressions in a report to the Royal Society.—T. G. B.

strata are seen always to strike towards the granite, and, in many cases, to be cut off sharply by it. The line of junction is far from being even or straight, for short dykes or masses of granite have been intruded between the beds.

The greater part of Mr. Allport's collection was obtained by following the line of junction, and represents the altered condition of the various beds through which the granite has broken. Hence it is reasonable to suppose that the differences in mineral character which they now exhibit are due to original differences in their constituents. Another group of specimens represents the rocks at a greater distance from any visible mass of granite. Of the former, Mr. Allport writes that the specimens indicate the nature of the rock, from its actual junction to a distance of about 12 yards from the granite, except in two instances, where the nearest mass of the latter was visible about 40 yards away. Here, however, the actual distance very probably is less, as the granitic mass slopes down beneath an intervening layer of turf.

Mr. Allport's collection contains some specimens from the granite *massif*, but it has not been thought necessary to have them sliced for microscopic examination. They show that, as might be expected, the rock varies considerably in texture and somewhat in mineral composition. Some are granophyres more or less porphyritic, others true granites. None are rich in quartz; one, in which biotite is abundant and a fragment of altered rock is included, is poor in this mineral. One contains small wine-red garnets. The dominant tint is some shade of grey.

Among clastic rocks, confining ourselves to the practically non-calcareous varieties, and putting aside the coarser breccias and conglomerates (none of which were seen by Mr. Allport in the district), we find every gradation from the finest clays either to pure quartz sandstones or to those miscellaneous grits which are often called greywackés. This old-fashioned and rather vague term may be conveniently used for a group of rocks especially common among the older Palæozoic strata of Britain.* These greywackés consist largely of quartz grains (often from 0·01″ to 0·02″ in diameter), with a fair proportion of fragments of about the same size or occasionally rather larger, among which the following may often be recognised:—(*a*) Composite quartz grains, including fragments of vein quartz and quartzite; (*b*) fragments of felspar of various species; (*c*) fragments of granitoid rock; (*d*) fragments of argillite and slate; (*e*) fragments of phyllite and fine-grained schists (generally mica-schist); (*f*) fragments of volcanic rock, glassy, cryptocrystalline, or scoriaceous. If one may generalise from a rather limited number of observations, the more acid lavas predominate over the basic, and among these

* Bonney, Address to Section C of the British Association, 1886 (Birmingham).

andesites or dacites seem more common. Mr. Allport's collection, as will be seen, represents the effects of contact metamorphism on rocks generally not rich in lime, and varying from silty clays to greywackés.

The minerals which have been produced by contact metamorphism, in the rocks now studied, do not require a lengthy description. In addition to what has been written in England, we are indebted to Professor Rosenbusch, Professor Barrois, and other foreign observers for some admirable studies.* Of these results, a very clear and full summary, up to a recent date, has been given by Mr. Teall,† so that it is needless to enter into details which may now be regarded as matters of common knowledge. The minerals in these specimens from Scotland are :—

(1) *Quartz*, which is very abundant, occurring both in small granules and in fair-sized grains, generally rather conspicuously free from inclusions.

(2) *Mica*, (*a*) brown, sometimes becoming greenish coloured, apparently from subsequent alteration,‡ (*b*) white.

(3) *Hornblende*. Occurs in grains of rather irregular outline, and not seldom interrupted by enclosures of quartz; sometimes rather acicular in habit and grouped. The length varies from about 0·01″ to 0·025″. Colour in thin sections a rather pale olive-green; pleochroism not very strongly marked; 𝔞, pale yellowish-green, 𝔟, olive-green or a rather deeper green. Some might certainly be called actinolite; the rest is nearer to one of the secondary hornblendes seen in epidiorites. Hornblende does not appear to be very common as a product of contact metamorphism in sedimentary rocks.

(4) *Augite*. Occurs in two or three slides with hornblende; in one case rather abundantly. In roundish or elongated grains of granular texture, almost colourless, or with the faintest possible tinge of greyish-green. Cleavage not very distinct, but sometimes grains show pretty clearly a cleavage parallel with ∞P, and then extinguish at angles often greater than 30°. Tints with crossed Nicols often brilliant. This mineral in general appearance resembles sahlite or malacolite, which are frequent contact products in limestone, so we may venture to regard it as a variety of augite.

* Lössen, 'Zeitsch. Deutsch. Geol. Gesell.,' vol. 19, p. 509; 21, p. 281; 24, p. 701; Kayser, *ibid.*, vol. 22, p. 103; Zirkel, *ibid.*, p. 175; Fuchs, 'N. Jahrb. Mineral.' (1870), p. 742; Barrois, 'Ann. Soc. Géol. du Nord,' vol. 11, p. 103; Lévy, 'Bull. Soc. Géol. France,' sér. 3, vol. 9, p. 181; Hawes, 'Amer. Journ. Sci.,' vol. 21, 1881, p. 21.

† 'British Petrography,' Chapter xii.

‡ See below for some remarks on this mineral.

(5) *Garnet* (rare).

(6) *Epidote* (?) not common.

(7) *Black opaque minerals* :—Iron oxide and perhaps graphite.

Tourmaline is extremely rare, three grains occurring in one slide only, from close to a junction, and, what is more remarkable, no andalusite is distinctly recognisable. One or two other minerals, which may be regarded as "accidental," will be noticed in connexion with the specimens.

As the effect of contact metamorphism has been described in some detail by one or other of the present authors from the Lake District, Cornwall and Brittany, and by Dr. C. Barrois from the last-named country,* it will suffice to recapitulate very briefly the phenomena, (*a*) in the case of a shale, (*b*) in that of a sandstone.

(*a*.) Very commonly chiastolite is formed in comparatively large crystals, and this even before the matrix of the rock is very obviously affected. As the junction with the intrusive mass is approached, the chiastolite crystals frequently disappear, and rounded spots of andalusite, often very full of mineral enclosures, begin to occur. These after a time become clearer and more crystalliform in outline.† Simultaneously, the colouring matter of the rock collects in specks, rods, and ill-formed crystals, the size of the last increasing on getting near the junction. Mica, usually of a peculiarly rich brown colour, forms in distinct flakes, which are sometimes interrupted by granules of quartz, &c., sometimes locally darkened by black spots, with an indefinite outline, like an ink blot on porous paper. The basal cleavage is distinct, but the external angles are usually not well defined. These flakes sometimes exhibit a certain parallelism, and thus impart a foliation to the rock, but this commonly is not well marked. Quartz, generally in clear granules, is also developed; sometimes it is wholly of secondary origin, but in other cases, probably, original fragments are enlarged, till the rock has become a crystalline aggregate, chiefly consisting of quartz and mica. As a rule, white mica, at any rate in crystals of fair size, only makes its appearance very near to a junction.‡

This brown mica is evidently not a normal biotite. There are in its microscopic aspect certain peculiarities by which it may generally be distinguished; for instance, the dichroism and absorption are less strongly marked, the colour-change being from pale-yellow to reddish-

* Allport, 'Quart. Journ. Geol. Soc.,' vol. 32, p. 407; Bonney, 'Quart. Journ. Geol. Soc.,' vol. 44, p. 11; Barrois, 'Ann. Soc. Géol. du Nord,' vol. 11, p. 103; see also Ward, "Geol. of Lake District" ('Survey Memoirs'), p. 9.

† On this line of change, as it does not occur in the specimens before us, it is needless to dwell.

‡ It is interesting to observe in connexion with this that MM. Fouqué and Lévy failed to produce artificially, by fusion, white mica, but met with some success in the attempt to obtain biotite ('Synthèse des Minéraux et des Roches,' p. 126).

brown, indeed often it becomes deep brownish-black and opaque. So far as we know this mica has not been isolated, and made the subject of quantitative analysis, but an inference may be legitimately drawn from the published analyses of clays and of rocks affected by contact metamorphism, in which the presence of this mineral has been determined by microscopic examination.

The researches of Carius, Fuchs, and Unger* may be held to have demonstrated that, as a rule, no change of any importance occurs in the chemical composition of a mass of rock affected by contact metamorphism. If, then, we examine a series of analyses of ordinary argillaceous sediments, and of the rocks resulting from contact metamorphism of the same,† we are struck with their comparative poverty in magnesia and richness in iron oxides. For instance, in a group of nine analyses, we find the following ranges of constituents:—

MgO, from 0·06 to 2·596; the average being 1·185.

FeO, from 0·495 to 6·010 }
Fe_2O_3, from 3·380 to 8·165 } the two together commonly forming from 9 to 10 per cent. of the whole.

K_2O, from a trace to 3·765, but generally more than 1·2 per cent.

Na_2O, usually in much smaller quantity, but once rising to 2·170 per cent.

Every analysis, except one, gives more than 2 per cent. of alkalies, but this records only traces both of soda and of potash. The author estimates that in one of these rocks—the richest in magnesia—there is 32·4 per cent. of mica, but even in this example the percentage of Fe to Mg is 11 : 9. Most of the analyses indicate less than half this quantity of magnesia, so that the amount of the iron would be three or four times that of the other constituent; indeed, we may say that in eight of these rocks the iron must largely exceed the magnesia, and in one of them almost wholly replace it.

The inferences thus suggested are confirmed by other examples from the Pyrenees, from the Lake District, and elsewhere. It is then evident that very many—probably most—argillaceous rocks do not contain a sufficient amount of MgO to form an ordinary biotite in any quantity, so that we must suppose either that the constituent is subsequently introduced—which is highly improbable—or that the mica is an iron mica, not a ferro-magnesian mica. Such micas are known to exist. We do not indeed remember to have seen a separate analysis of the mica from a case of contact metamorphism, but in the table of analyses of black mica given by Mr. Teall,‡ we find one with MgO as low as 1·50 (FeO, 18·06; Fe_2O_3, 7·19), and similar micas are

* Fuchs, 'Neues Jahrb. f. Mineral.,' 1870, p. 742; Unger, *ibid.*, 1876, p. 785.

† Such as are given by Unger, 'Neues Jahrb. f. Mineral.,' 1876, p. 785.

‡ 'British Petrography.' p. 302.

analysed by Mr. F. W. Clarke,* from American localities. In fact, these contact-micas are either lepidomelanes or haughtonites, varietal names which are applied to iron micas, according as there is a predominance of Fe_2O_3 or FeO.†

The same analyses indicate that if a normal clay were converted into a quartz-mica rock, supposing all the alkalies present to be taken up in forming mica, a considerable proportion of alumina, and the larger part of the silica (something like 50 per cent.) would be left unused. If the alumina amounted to 11 per cent. of the whole, about 6·6 of the silica would be required for andalusite; this would leave not less than 43 per cent. of the silica free to form quartz. Thus from a normal clay, as the result of contact metamorphism, a rock is produced containing not less than 50 per cent. of free quartz.

(*b*.) After what has been said above, the history of a sandstone may be dismissed in few words. Almost all sandstones contain a certain amount of mud and silt. From these, both mica and subsilicates of alumina would form as before; but in this case the free silica would very commonly be deposited on the pre-existing granules or grains of quartz, probably in crystalline continuity with them, so that in many cases the fragmental aspect of the rock would be obliterated and its structure would resemble that of the quartz layers in the true crystalline schists.

In the above cases, if the original rock contained a lower proportion of alkalies and a fair one of lime, as well as some magnesia, we might expect minerals of the pyroxene group to be formed. If, however, felspar was present in fragments, and its constituents entered into new combinations, a white mica might be produced. A fragment of normal orthoclase, in forming muscovite, would liberate at least four-tenths of its silica,‡ and if it had lost some of its alkaline constituents by decomposition, it would be converted into a roughly equal mixture of quartz and muscovite.

Somewhat similar changes would occur in the case of fragments of an acid glass, which might be expected to produce, as the result of contact metamorphism, a microcrystalline mixture of quartz and white mica, while the alteration of a basaltic rock§ would give rise to pyroxenic minerals, epidote, probably some biotite or chlorite, with a smaller proportion of quartz.

On examining some of the slides in Mr. Allport's collection from

* 'Amer. Journ. Sci.,' vol. 34, 1887, p. 131.

† Mr. Allport ('Quart. Journ. Geol. Soc.,' vol. 32, p. 417) found that lithia was present in Cornish specimens of the brown contact-mica, but probably this is not an essential constituent.—T. G. B.

‡ Bonney, 'Quart. Journ. Geol. Soc.,' vol. 44, p. 37.

§ Allport, 'Quart. Journ. Geol. Soc.,' vol. 32, p. 407, &c.

Scotland, we are at once struck, notwithstanding the present crystalline condition of the rocks, with their resemblance to those cut from greywackés, which contain distinct fragments of quartz, felspar, and an argillaceous rock. We do not, indeed, observe an indubitable fragmental structure, but what we might term the ghost of one. For instance, the eye is at once arrested by subangular grains of quartz, which are much larger than those helping to form the mosaic of quartz and mica which constitutes the major part of the rock. Their edges are sometimes sharply limited by flakes of brown mica and are rectilinear, at others they join irregularly to the quartzes of the matrix, as if they had grown together. Sometimes these larger grains show a compound structure, but more often they are simple, part of a single crystal, just as may be seen in the fragments common in a greywacké. Usually they are fairly free from enclosures, though occasionally microliths and small fluid cavities with bubbles may be observed. Other patches, yet more shadowy in outline, consist of chalcedonic or microcrystalline quartz and flakelets of mica, generally white. Still, it is generally not difficult to distinguish them from the matrix, owing to their difference in composition and structure. Careful examination of these detects occasionally less altered portions in which the lamellar twinning of a plagioclase felspar is still distinctly recognisable. These, then, represent the felspar fragments of the original greywacké. Again we note other subangular fragments, which consist sometimes of fair-sized quartz-granules together with a little dark-coloured mica, or perhaps an iron oxide, sometimes of smaller quartz-granules and of brown mica. Comparing these with specimens of fine-grained earthy sandstones, silts, and shales, affected by contact metamorphism, which we have obtained from other localities,* we find a perfect correspondence in composition and structure, and have no hesitation in regarding them as representatives of bits of arenaceous and argillaceous rock, once present in the original greywacké. Fragments of granitoid or of volcanic rock have not been positively identified in the present set of slides, though very probably the former, at any rate, would be found, if a larger series was prepared. The matrix of the original rock, once a silt of variable composition, is now replaced by quartz and mica (generally brown), with sometimes a considerable proportion of a pyroxenic mineral, which appears to substitute itself for the brown mica.

In conclusion, a few remarks may be made upon the specimens. The first group (see above, p. 194) was taken from near the granite mass. All the specimens have a hard, strong appearance; some show a slight mineral banding, but there is no well-marked foliation; thus the texture of the rock at the first glance reminds one more of a rather micaceous band in those granulitic rocks which are generally

* Bonney, 'Quart. Journ. Geol. Soc.,' vol. 44, p. 11.

found to be of Archæan age, and of which the origin is still doubtful, than of a normal mica-schist. They exhibit that peculiar purplish-brown or purplish-grey tint which is so common in the quartz-mica rocks resulting from contact metamorphism, and is doubtless due to the peculiar tint of the micaceous constituent.

Of the first three specimens, 406, 407, 408,* taken from the same locality, about 12 yards from the granite, we need only remark that one exhibits, macroscopically and microscopically, a slight mineral banding, indicated by variations in the proportions of the quartz, mica, and a brownish earthy-looking dust, which are the chief constituents of the rock. To this banding the flakes of mica tend to lie roughly at right angles. In the other two specimens, fragments of quartz and of altered felspar can be detected. In one the latter is abundant, and the frequency of an earthy dust, and of a mixture of microcrystalline quartz with tiny flakelets of mica or a kaolinitic mineral, renders it probable that the original rock was a rather felspathic grit. A vein of calcite is present in the slide. The other specimen possibly contains a little andalusite.

The next specimen (409) exhibits fragments rather distinctly, some being about 0·05″ in diameter. In those of felspar traces of twinning can be detected, showing the mineral to be either a plagioclase twinned on the pericline type or a microcline. The matrix is more free from "dust" than in the former specimens, so that the rock has a more distinctly holocrystalline aspect. A few grains of epidote are probably present.

The next two specimens (410, 411) were collected about 40 yards from the nearest visible granite. Both assume a tinge of green in weathering. One differs little from some of those already described; the other is macroscopically rather distinctly "spotted;" both exhibit light specks such as might indicate a felspar, and elongated darkish spots or streaks lying roughly parallel. Hornblende is rather abundant, associated with or replacing the brown mica; also a few grains of pyrite. There are fragments as above described, one or two reaching 0·04″ in diameter; the presence also of rock fragments is suggested, but the evidence is inconclusive. From the condition of the matrix one would infer a rather earthy condition for the original grit.

The next specimen (414) is from a junction, and a vein of light coloured, finely granular, non-micaceous granite, about $1\frac{1}{2}''$ thick, is present in the hand specimen. The altered rock is rather more coarsely crystalline in aspect than the others, white mica is present in fair-sized flakes, and there are many irregular blackish spots, like stains, about 0·14″ diameter. Microscopic examination shows that a fragmental structure is still marked, and that bits of rock are present.

* These numbers are painted on the specimens.

Much of this must once have been a more or less sandy argillite. One or two, however, suggest the former presence of a fine-grained quartz-felspar rock, probably a micro-granite, the felspar of which has been replaced by a minute fibrous mineral, the fibrillæ of which exhibit bright tints when rotated between crossed Nicols, and give straight extinction; probably it is sillimanite. White mica is present in rather considerable quantity, in thickish flakes up to about 0·04″ in longer diameter. Sillimanite is also present in the matrix, and in parts of the slide a clear mineral, varying in colour from orange to rich burnt-sienna brown, forms a kind of base to the small round grains of quartz and flakes of brown mica. This material has but a weak depolarising power. It exhibits an aggregate structure, and appears to be in rather close relation with the above-named fibrous mineral. It may be only a stained variety of the same, or possibly an alumina-subsilicate nearly related to staurolite.*

Proceeding onwards, the next specimen (415), taken about 10 yards from the junction, is macroscopically very distinctly speckled, and under the microscope indicates very clearly the presence of fragments. These are quartz and felspar as usual, an altered argillite, and in one case an impure fine-grained sandstone or quartzose silt. In the matrix is a considerable amount of hornblende.

The next specimen (416), collected about 200 yards north of the last, contains no hornblende, and is less definitely fragmental. The flakes of brown mica are not seldom about 0·01″ long, and occasionally rather more. They indicate a slight foliation, and are frequently crowded round the quartz grains, the latter being unusually clear and free from enclosures.

The next two specimens (417, 418) illustrate a rock with bands of brownish and greenish-grey. Fragments are present, as above described, some evidently have been fine-grained sandstones, a few probably an argillite. The amount of these and the changes in the matrix from the ordinary quartz-mica rock to layers where a pyroxenic mineral replaces more or less the mica, indicate that the original rock was composed of stratulæ of different nature, and a slight foliation may be noted parallel with the original bedding. Some of the pyroxenic mineral is hornblende, but in parts of the slide an augite is abundant, as described above.

The last specimen (419) from this locality gives less distinct indications of original fragments, and differs only from the ordinary quartz-mica rocks in being rather more definitely foliated.

The next two specimens (420, 421) were collected at Newton Stewart Road, about $\frac{1}{4}$ mile from the granite, from beds which struck

* A rather similar mineral occurs in a junction specimen from Sinen Gill, Skiddaw, but here its structure is more uniform and its influence on polarised light more marked. This very probably is staurolite.

towards it. Both are slightly foliated. One (not sliced) is the ordinary finely granular quartz-mica rock, but having some thin pale-green laminæ; the other, in which the greener bands predominate, occurs about 5 yards above it. In the slide there is very little brown mica, the pyroxenic constituent predominating. Most of this is hornblende, but some may be the augite already described. There is a little of what seems to be dirty calcite, and a few grains which may be either an impure epidote or possibly sphene. Rock fragments cannot be distinguished; probably the rock was originally a rather fine-grained earthy grit. Occasionally the pyroxenic minerals lie with their longer axes at a high angle with the general foliation of the rock.

The remaining specimens (422, 423) are from near a bridge over the Ken, about 1½ miles from the nearest visible granite, and on the line of strike of the last named. The macroscopic aspect of the one is perplexing. In some respects it resembles an ordinary, fairly coarse mica-schist, rather crushed out and cleaved; in some a schistose micaceous grit; while in some it recalls the specimens above described. In any case it evidently has been affected by pressure. Microscopic examination discloses a distinctly fragmental structure, but in addition some mineral change. The rock mainly consists of grains and granules of quartz, and of flakes of mica of every tint, from almost white to olive-brown, and of variable dichroism, with earthy grains and specks indicating the presence of iron oxides and of an aluminous mineral; a few better preserved fragments are also present, which are almost certainly more or less altered felspar.* There is a little recognisable epidote, and one or two small zircons. The quartz is no doubt in part secondary, but the larger grains have a distinctly fragmental aspect; these occasionally measure about 0·03″ in their longer diameter, but commonly not more than 0·01″. Sometimes the boundary is fairly sharply defined, but generally (especially at the ends of the grains, that is, in the direction of the foliation planes) small mica flakes seem to pierce the edge. This appears to indicate that there has been some secondary enlargement. The grains are occasionally composite, but generally homogeneous; they are rather free from cavities, bubbles or other enclosures, but now and then they enclose microliths, especially of pale-coloured mica. The latter mineral, in like way, is sometimes collected in elongated patches, suggestive of a flaky fragment, sometimes scattered in the ground-mass. The single flakes occur up to about 0·005″ in length, but usually are between 0·001″ and 0·003″. As described by one

* One of these, which may be either a felspar or one of the andalusites, exhibits roughly parallel lines of dark belonitic enclosures, as described by Professor Bonney ('Quart. Journ. Geol. Soc.,' vol. 45, p. 100). These make an angle of about 30° with the general direction of foliation, and are clearly antecedent to it.

of us in the case of the Obermittweida conglomerate,* the mica appears to be partly original, partly secondary; indeed, repetition may be saved by referring to the published description of the grit from the inner part of the fold at that place, merely stating that in it secondary changes appear to be rather more pronounced than in the present specimen.

The other specimen is a homogeneous, compact, very fissile rock, like a schistose slate or phyllite. Microscopic examination shows that it consists of a micaceous mineral and quartz, with occasional granules of epidote (rare), of an impure kaolinitic mineral, and flakes or perhaps rods of iron oxide. In most parts of the slide these are the chief constituents. The flakes of the first-named mineral occasionally, in the more quartzose parts, are about 0·0025″ long, but generally less. It varies from almost colourless to a pale olive tint, but sometimes is slightly brown. It often resembles a mineral common in some of the oldest green slates, and some of it is probably a chlorite. The associated quartz is generally very minute, but rather larger grains of distinctly fragmental aspects, up to about 0·004″ in diameter, occur, especially in certain layers, and there are others consisting mainly of quartz. It is, however, possible that some of these may be veins, indeed, one of the most quartzose certainly is, but others are hardly less certainly true stratulæ, indicative of former bedding. The sharp flexures in these, the "rucking" of the layers of mica, and the development in parts of the slide of an incipient strain-slip cleavage (*ausweichungs-clivage*) indicate that the rock, subsequent to partial mineralisation, underwent great pressure. In short, macroscopically and microscopically, it bears considerable resemblance to those "satiny" slates or phyllites, the alteration of which is, to a very large extent, due to pressure. At the same time, when we examine the individual plates of mica and the structure of the folds with a high power, we are led to think that some subsequent modifications have taken place. As has been described in the paper already mentioned, each individual flake of mica appears as if the process of formation had been completed *in situ*, or that in some way or other it had been enabled to "right itself" after the distortion which is usually produced by these great earth-movements. So also the layers of mica, as it were, slightly bristle with the projecting ends of mica flakes; at the sharpest part of a fold they have lost the "strained" look, like a rope beginning to part, and the incipient plane of strain-slip cleavage is often "soldered up." The changes have taken place (though to a much less extent), which are described in the paper by one of us on the effect of contact metamorphism on phyllites at Morlaix.† Probably we shall not be wrong in ascribing them to the elevation of temperature, connected

* 'Quart. Journ. Geol. Soc.,' vol. 44, p. 29.

† 'Quart. Journ. Geol. Soc.,' vol. 44, p. 12.

with the granite intrusion above described, though in the present case the greater distance from the granite would make this elevation a less important agent of change.

The specimens which have been described indicate that from ordinary muds and sandy silts, quartz-mica (and in some cases quartz-pyroxene) rocks may be developed by contact metamorphism, and that the differences now to be observed in the mineral composition are due to differences in the original sediments of which the mass was composed. In some cases the rock has become thoroughly crystalline, in others the process is less complete, and a fair quantity of the original dust, possibly in the form of kaolin, still remains. If fragments of larger size have been present, these, though modified like the matrix, can still be recognised. Some of these rocks are no less crystalline than certain of the less coarsely crystalline mica-schists, and occasionally exhibit a foliation. From the latter, however, they can be distinguished by a practised eye. They are fair imitations of some of the indubitably Archæan quartzose mica-schists, but only imitations. Heat has been the main agent of metamorphism in the case of the rocks just described, though probably water was present, and considerable pressure may also have been exercised, which in one case seems to have produced an earlier alteration. Where the original constituents have differed considerably in size, a record of this structure is still retained. Had the elevated temperature been maintained for a longer time, molecular movements among the constituents might have rendered this structure more indistinct, but there is nothing to warrant the supposition that they could have obliterated the distinction between stratulæ of moderate thickness. These specimens then appear to justify us in asserting a sedimentary origin for certain crystalline schists (micaceous, quartzose, &c.), in referring their mineral bands to a stratification of the materials, and in supposing their alteration due to their having been kept at a comparatively high temperature for a considerable period.

III. "On some Variations of *Cardium edule*, apparently correlated to the Conditions of Life." By William Bateson, M.A., Fellow of St. John's College, Cambridge, and Balfour Student in the University. Communicated by Adam Sedgwick, F.R.S. Received May 13, 1889.

(Abstract.)

In 1886 and 1887 I made a journey to some of the lakes of Western Central Asia for the purpose of making observations on their fauna. As the waters of these lakes are of very various composition, being salt, alkaline, bitter or fresh, in different degrees, I looked forward